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525 Rec'd PCT/PTO 05 JAN 2001

FORM PTO-1390 (REV 10-2000) U S DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER
MUR-8558US

U S APPLICATION NO (If known, see 37 CFR 1 5)
09/743164

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/GB99/02082	12 July 1999	11 July 1998

TITLE OF INVENTION
IMPROVED PROCESS MONITOR

APPLICANT(S) FOR DO/EO/US
Mark Burton Holbrook, William George Beckmann, and Jacques Andre Grange

Applicant herewith submits to the united States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to promptly begin national examination procedures (35 U.S.C. 371(f)).
4. ☒ The US has been elected by the expiration of 19 months from the priority date (PCT Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. ☒ is attached hereto (required only if not communicated by the International Bureau).
   b. ☐ has been communicated by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. ☐ are attached hereto (required only if not communicated by the International Bureau).
   b. ☐ have been communicated by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☐ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☒ A copy of the International Preliminary Examination Report (PCT/IPEA/409) with Annex (amended claims).

Items 11 to 16 below concern documents(s) or information included:

11. ☒ An Information Disclosure Statement under 37 U.S.C. 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A FIRST preliminary amendment.
    ☐ A SECOND or SUBSEQUENT preliminary amendment.
14. ☐ A substitute specification.
15. ☐ A change of power of attorney and/or address letter.

☐ Other items or information:

500 Rec'd PCT/PTO 05 JAN 2001

U S APPLICATION NO (If known, see 37 CFR 1 5)	INTERNATIONAL APPLICATION NO.	ATTORNEY DOCKET NUMBER
09/743164	PCT/GB99/02082	MUR-8558US

16. ☒ The following fees are submitted:

BASIC NATIONAL FEE (37 CFR 1.492(a)(1) – (5)):

☐ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO....... **$1000.00**

☒ International preliminary examination fee (37 CFR 1.482)not paid to USPTO but International Search Report prepared by the EPO or JPO **$860.00**

☐ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO **$710.00**

☐ International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4) **$690.00**

☐ International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4) **$100.00**

CALCULATIONS PTO USE ONLY

				CALCULATIONS	PTO USE ONLY
ENTER APPROPRIATE BASIC FEE AMOUNT =				$ 860	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 Months from the earliest claimed priority date (37 CFR 1.492(e)).				$	
CLAIMS	NUMBER FILED	EXTRA NUMBER	RATE		
Total claims	31- 20 =	11	X $18.00	$ 198	
Independent claims	3 - 3 =	0	X $80.00	$ 0	
MULTIPLE DEPENDENT CLAIM(S) (if applicable) ☐			+ $270.00	$ 0	
TOTAL OF ABOVE CALCULATIONS =				$ 1,058	
☐ Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by ½.				$	
SUBTOTAL =				$ 1,058	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 Months from the earliest claimed priority date (37 CFR 1.492(f)). +				$	
TOTAL NATIONAL FEE =				$ 1,058	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property +				$	
TOTAL FEES ENCLOSED =				$ 1,058	
				Amount to be refunded:	$
				Charged:	$

a. ☒ A check in the amount of **$1058** to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. ______ in the amount of $______ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. **18-0350**. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

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19,717
REGISTRATION NUMBER

January 5, 2001
DATE

09743164 . 010501

MUR-8558US

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	Mark Burton Holbrook, William George Beckmann, and Jacques Andre Grange	: Interntl Serial No.: PCT/GB99/02082
Serial No.:	(to be assigned)	: Interntl Filing Date:
Filed:	(herewith)	: 12 July 1999
FOR:	IMPROVED PROCESS MONITOR	:

PRELIMINARY AMENDMENT

Assistant Commissioner for Patents
Washington, D.C. 20231

SIR:

Preliminary to examination in the United States Patent and Trademark Office, please make the following amendments in the above-identified application in order to place it in condition for examination.

Amend the specification by inserting before the first line the sentence:

This application is the U.S. national phase application of PCT International Application No. PCT/GB99/02082 filed 12 July 1999.

IN THE CLAIMS:

Please amend the claims as follows:

3. (Amended) A method as claimed in [any one of] Claim[s] 1 [or 2], wherein the process is plasma based.

4. (Amended) A method of processing a semiconductor workpiece including determining the process progress as claimed in [any one of] claim[s] 1 [to 3] and controlling the process in response to the indication provided.

16. (Amended) A process control system as claimed in [any one of] claim[s] 12 [to 15], including a digital filter for determining the shape of the time evolving spectral output.

17. (Amended) A process control system as claimed in [any one of] Claim 12 [to 15], wherein the shape recognition is achieved by a series of masks derived from different time epochs using a Gradiometer transform

18. (Amended) A process control system as claimed in [any one of] Claim[s] 12 [to 15], wherein the shape recognition is achieved by a series of masks derived from different time epochs using a Fourier Transform.

19. (Amended) A process control system as claimed in [any one of] claim[s] 12 [to 15], wherein the shape recognition is achieved by a series of masks derived from different time epochs using a Laplace Transform.

20. (Amended) A process control system as claimed in [any one of] claim[s] 12 [to 15], wherein the shape recognition is achieved by a series of

masks derived from different time epochs using the Kohonen self organising map.

21. (Amended) A process control system as claimed in [any one of] claim[s] 12 [to 15], wherein the shape recognition is achieved by a series of masks derived from different time epochs using the cellular neural network paradigm.

22. (Amended) A process control system as claimed in [any one of] claim[s] 12 [to 15], wherein the shape recognition is achieved by a series of masks derived from different time epochs using Polynomial Interpolated Measures.

23. (Amended) A process control system as claimed in [any one of] claim[s] 12 [to 15], wherein the shape recognition is achieved by a series of masks derived from different time epochs using the method of Fractals.

24. (Amended) A process control system as claimed in [any one of] Claim 12 [to 23], wherein the spectral detection means includes a dispersive grating monochromator.

25. (Amended) A process control system as claimed in [any one of] claim[s] 12 [to 23], wherein the spectral detection means includes a scanned 'Fabry-Perot' interferometer.

26. (Amended) A process control system as claimed in [any one of] Claim[s] 12 [to 23], wherein the spectral detection means includes a Fourier Transform Spectrometer.

27. (Amended) A process control system as claimed in [any one of] claim[s] 12 [to 26], wherein a multiplicity of spectrum parts are examined simultaneously.

28. (Amended) A process control system as claimed in [any one of] claim[s] 12 [to 26], wherein the spectral detection means detects the absorption spectrum of light of a particular characteristic wavelength.

29. (Amended) A process control system as claimed in [any of] claim 28, including a laser as a light source for providing the light of the particular wavelength.

30. (Amended) A process control system as claimed in [any of] claim[s] 29, including a frequency swept laser as the light source.

31. (Amended) A process control system as claimed in [any one of] Claim[s] 12 [to 26], wherein the process is plasma based.

Respectfully submitted,

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Dated: January 5, 2001

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The Assistant Commissioner for Patents is hereby authorized to charge payment to Deposit Account No. **18-0350** of any fees associated with this communication.

EXPRESS MAIL Mailing Label Number: **EL736965876US**
Date of Deposit: **January 5, 2001**

I hereby certify that this paper and fee are being deposited, under 37 C.F.R. § 1.10 and with sufficient postage, using the "Express Mail Post Office to Addressee" service of the United States Postal Service on the date indicated above and that the deposit is addressed to the Assistant Commissioner for Patents, U.S. Patent & Trademark Office, Washington, D.C. 20231, Attn: BOX PCT/EO/US.

Kathleen Libby

Kathleen Libby

09/743164
PCT/GB99/02082
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8/PRB

"Improved Process Monitor"

This invention relates to the field of the deposition, removal or modification of thin films and/or substrate materials.

Thin films are commonly used to modify surface properties, and processes occurring in vacuum apparatus are commonly used to deposit/remove or modify these films and for some applications this modification extends to the underlying substrate material. Typical applications include the coating of optical components to improve their light transmission or reflection properties, the coating of composite materials to improve adhesion behaviour, the coating of semiconductors to introduce insulating, conducting or indeed other layers with specific electronic, optical, magnetic or mechanical properties, and the production of ultra-small three dimensional structures for use in sensors and computer based recording devices. Typically these films and structures will have dimensions from 1μm to several hundred microns. Frequently the films are structured in stacks where there is a change in chemical composition from one layer to the next. Such stacks vary from the simplest

of one material on top of another to several hundred different layers in sequence.

In order for these structures to carry out the function for which they have been designed these materials frequently have to be etched, deposited or, once having been deposited, have to be removed or transformed (eg annealed) wholly or partially with very great precision. This deposition or removal is frequently carried out under conditions of vacuum using temperature controlled environments and gas or gases excited into the plasma state. It is beneficial to carry out measurement in-situ of the deposition or removal. Such processes generate considerable quantities of electrical, thermal, optical, vibrational and Radio Frequency noise.

This invention improves the process control of these deposition, etch or modification processes under these inherently noisy and difficult conditions.

In this field it is already known that the light emitted from a plasma may be used to determine the composition of the active species and the chemical concentration occurring at any particular time (Goffered G.G., SPIE Vol 1392, p454-p459). The described technique of measurement for process control is preferred by many users over alternatives such as quartz crystal microbalance or resistivity measurements or the like in that it is non-invasive, but as indicated below, it suffers considerable problems with noise. Alternative non-invasive techniques such as laser reflectometry (JVSTE 12 (6)p3306 '94 and WO98/07002) exist but they demand the careful set up of a light source reflecting from the sample and can limit the geometry of the processing chamber or the location

of ancillary equipment. Mass spectrometry provides an alternative but it has the disadvantage of requiring to extract a sample for analysis which has concomitant problems with individual lifetimes of particular chemical species.

In its simplest form the spectral emission method provides a convenient remote measurement technique so that if it is tuned selectively to measure the concentration of element 'A' and an etch process is occurring to remove films consisting predominantly of element 'B' placed on top of and obscuring a substrate consisting of element 'A', then when the etch reaches down through all of the overlying film the signal representative of element 'B' will fall to a very small value to be replaced by a signal representative of element 'A'. This idealised 'step change' in the signal is in principle very easy to detect and a simple level change algorithm will allow automatic detection of the breakthrough point and thus automation of the film removal process. The establishment of several tuned channels of measurement (which may be realised as individual channels or a multiplexing scheme) permits simultaneous measurement of a number of characteristic spectral outputs which can help in discrimination.

The above known art has the disadvantage that the signal change is frequently not a simple abrupt step. Furthermore pulsed processes are being used more commonly now in order to improve process efficiency. In addition the frequency profile of the signals themselves may form complex shapes with either a lot of fine detail (in the form of many lines) or alteratively with very little fine detail (in the form of a continuum). The nature of the physical situation is therefore such that the exact determination of a

process endpoint achieving good run-reproducibility requires extensive calibration and a high level of skill on the part of the process technician setting up the process control using spectral emission from the plasma etch, deposition or surface modification process. It is the objective of this current invention to provide for improved process control using spectral emission from a plasma process.

During the process some skilled operators will examine the behaviour in time of the emitted light characteristic of a particular constituent component in the plasma in an attempt to compare it to the behaviour that they noted during the calibration procedure. This relies on the constant presence of the operator and is not repeatable between operators.

From one aspect the invention consists in a method of automatically determining the progress of plasma processing including continuously monitoring a predetermined frequency or frequency band of radiation emitted from or absorbed by the plasma, developing a graphical or numerical output corresponding to the level of emittance or absorption, and electronically comparing that output with a predicted output or predicted trend to provide an indication of the progress of the process.

From another aspect the invention consists in a process control system for controlling a plasma based process including means for continuously capturing a frequency limited sample of radiation from a plasma, a detector for producing an output indicative of the time varying intensity of the radiation, and shape recognition means for comparing the output against a predicted output or trend to provide an indication of the progress of the

process.

From another aspect the invention consists in a process control system for controlling a plasma based process including means for continuously capturing a predetermined range of frequencies and prior to conversion to an electrical signal using a shape recognition means to identify characteristic shapes in the spectral domain. The refined signal is then incident on a detector means for producing an output which is indicative of the time varying intensity. A shape recognition means is then employed in the time domain for comparing the output against a predicted output or trend to provide an indication of the progress of the process.

From another aspect the invention consists in a process control system for controlling a plasma based process including means for continuously capturing a predetermined range of frequencies and after their incidence on a detector means using a shape recognition means to identify characteristic shapes in the spectral domain. The refined signal is then indicative of the time varying intensity. A shape recognition means is then employed in the time domain for comparing the output against a predicted output or trend to provide an indication of the progress of the process.

From a still further aspect the invention consists in a process control system where a time evolving spectral output from a plasma is detected by a spectral detection means and then used in combination with the application of shape recognition techniques to provide a continuous measure of process progress against a predicted trend.

Thus in embodiments of the invention the spectral output of the plasma system is being monitored by shape recognition techniques. Filters can be established in the time, frequency and optical frequency domains which respond to particular characteristic forms. The predicted signal behaviour is examined for these characteristic forms prior to running the process yielding a data set that is indicative of process progress towards an endpoint. During the process run that is required to be automated the actual data train is interrogated by the same shape recognition filter set yielding a pointer position against the predicted behaviour which is constantly updated permitting complete access at all times to a measure of status of the etched position or other process.

While further modifications and improvements may be made without departing from the scope of this invention, the following is a description of examples of the invention, referring to the drawings, in which:

Fig. 1 shows the typical optical transmission of a thin film filter;
Fig. 2 shows the typical optical transmission of a 'Fabry-Perot' etalon;
Fig. 3 shows the typical optical transmission of the combination of a thin film filter with a 'Fabry-Perot' etalon;
Fig. 4 is a schematic illustration of a preferred embodiment of the apparatus of the invention;
Fig. 5 shows a typical output signal from a detector of the apparatus of Fig. 4;
Fig. 6 is a flow chart illustrating data processing carried out in one form of the invention;
Fig. 7 illustrates an alternative embodiment of

data processing.

Fig. 8 is a graph illustrating a modified application of the invention; and

Fig. 9 illustrates graphically a further modification.

Referring particularly to Fig. 4, in a typical process a silicon substrate 11 to be etched is masked with a two-dimensional pattern of photo resist and containing within the depth of the silicon structure a buried layer of silicon oxide, in a manner well known per se. The substrate 11 is placed in a plasma reactor system comprising a vacuum vessel 8 which is provided with vacuum pumping means (not shown) and electrodes 9 and 10. The substrate 11 is placed close to or on one of the electrodes 9, 10.

The etch system is provided with a plasma excitation means 6 and a gas control means 7. In the preferred embodiment at least one of these is pulsed so as to provide a cyclically varying environment in the vacuum chamber 8.

A window 12 allows optical radiation from the plasma to be incident on a mechanism which is provided for computing a particular spectral line of the plasma emission and consisting of a thin film filter 13 which is followed by 'Fabry-Perot' etalon 14 that has been suitably adjusted to isolate radiation that shows cyclical behaviour characteristics of the particular process. The output of 'Fabry-Perot' etalon 14 is incident on a detector means 15 which produces an output indicative of the instantaneous intensity of the selected spectral frequency. The detector means 15 then passes its output signal to a signal processing means 16 within which shape recognition algorithms

analyse the signal and produce a control signal to indicate when a predetermined event has occurred or to produce a continuous report on the progress of the process.

As seen in Fig. 1, the narrow band filter 13 provides a convenient means for isolating a particular spectral line but in general it is not precise enough in its response to isolate a particular line to the exclusion of other lines that may interfere with it. The typical band pass 1 of such a filter is approximately 5 nanometres.

The 'Fabry-Perot' etalon 14 on the other hand, as seen in Fig. 2, provides a very sharp spectral response but also allows adjacent sharp responses which are relatively close in frequency terms. The individual optical passbands are typically very narrow at about 0.2 nanometer but there is a multiplicity of them separated at typically 10 nanometres.

The combination of the two elements, Fig. 3, provides a means for convenient isolation of particular spectral lines. With suitable angle tuning of the 'Fabry-Perot' etalon, a single narrow passband is obtained at a frequency characteristic of the etch process being monitored.

Suitable thin film filters and 'Fabry-Perot' etalons will be readily apparent to those skilled in the art. As one example, suitable elements are those available from Melles Griot Technical Optics Limited of Onchan, Isle of Man. Likewise, the detector may be any detector suitable to handle the optical output; as one example, we have used a photomultiplier tube by Hamamatsu.

Gaseous precursors are chosen so that with one particular concentration of components and with particular levels and bias of Radio Frequency or microwave power the silicon material is etched. With reference to the cyclic etch/passivation method of forming features in the workplace, the etch and passivation steps are discrete; see for example published PCT application WO-A-9414187, the contents of which are hereby incorporated by reference.

The output signal from the detector 15 (Fig. 5) shows a characteristic wavetrain in time consisting of repetitive double peaks. The repetitive signal is due to the cyclical nature of the process. The distinctive double peak shape is due to the etch of polymer followed by the etch of silicon. The overall signal is superimposed on noise from a variety of sources including optical noise and time jitter pulsing when a deposition/etch cycle is used. The characteristic shape of the time development of the spectral line signal is provided by an array of digital filters with impulse responses matched to the characteristics of the different time epochs. This array of filters can be progressive and examine longer time segments as the end point of the process approaches. The historical match to longer segments of characteristic signal shape increases the confidence of measure of exactly where in the process progression the etch is at any particular time.

More specific examples of the shape recognition process will now be described.

Referring to Fig. 6, which illustrates in flow-chart form the data processing carried out in the preferred embodiment, an idealised prediction of the signal

obtained from the process scanned by a data window 91 which, in the preferred embodiment, may be a data window extending to 1/3000 of the data size. The contents of the data window 91 are then passed to a software routine 92 that analyses frequency. In the preferred embodiment this is a Fast Fourier Transform. The output of the Fast Fourier Transform 92 is then used to construct an adaptive digital filter 93 that passes the frequencies present as being predicted to be present in the data window 91 and highly attenuates other frequencies. The output of the digital filter 93 is recorded as the processed signal against time 94. The digital filter 93 is then used to carry out a shape recognition 95 as compared to the idealised prediction 90. In the preferred embodiment this shape recognition 95 may be accomplished by a correlation of the Fourier spectrum of the processed signal against the Fourier spectrum of the idealised signal. The output of the shape recognition 95 then yields a best match which is the parameter 96 at any point in time of the processed signal. This value is then compared to the target process condition to give a termination On/Off decision. Also this value is compared at 98 to time to give a rate signal which may be used for closed loop process control.

If there is inadequate knowledge of the process to allow a full idealised signal to be produced, the shape recognition may be achieved by a calibration run. In Figure 7 the unprocessed signal output 100 of an etch process is then processed by a digital filter 101 using filter parameters derived from keyboard entry 102. The output of the digital filter 103 is then compared to any predictive modelling or prior experience of film shape to ensure that representative features are present. This processed calibration run is then

calibrated against a desired etch by an off-line technique such as stylus profiling. The resulting calibration data set 105 is then used in exactly the same way as the idealised signal data set 90 in the previous preferred embodiment.

The skilled reader will understand that the method for analysing frequencies may be of many different types such as cosine, sine or Laplacian methods. The skilled reader will also understand that the shape comparison technique may be achieved by many techniques including Laplace Transforms and Gradiometer Transforms. The data windows may also be of varying extent. The data set that is to be compared to, which may be an idealised data set resulting from a model or a calibration data set, is used in conjunction with a range of data windows. These data windows increase in length from one to the other so that if confidence of recognition of shape by a correlation technique using the Fast Fourier Transform or a Laplacian Technique, or application of any other shape recognition method such as the Gradiometer Transform, falls below a pre-defined minimum level then the subsequent increased size window may be used. Use of a data window of increased size has the advantage of allowing more data to be used to recognise features. It has the concomitant disadvantage that more data has to be present in the processed data stream to allow a meaningful comparison but, since the movement to a larger data window only occurs after more processed data has been already collected, this disadvantage has no impact on the availability of process data. Under circumstances where it is desirable for the confidence of fit to be very high, it may be desirable to use data windows only varying by a very small amount from each other and to automatically change from one data window to the

subsequent one rather than waiting for an inadequate fit to be recorded.

It should be understood that although the example cited is that for cyclic (etch/passivation) etching of silicon, other materials can be etched or other plasma process performed under the control of the present method and system.

The advantages of the invention are that the use of shape recognition techniques automates the plasma process allowing for unattended operating and the rapid commissioning of process. A further advantage of the technique is that use of the shape and trend of the curve as opposed to traditional level discrimination increases the immunity of the measurement to noise source including shot to shot noise arising from time jitters in a pulsed process. A further advantage of the technique is that the shape recognition method yields a confidence of fit at all points along a predicted curve which in addition to endpoint detection provides measures which can be used for continuous optimisation of the process parameters.

A further advantage is that light from the plasma can be obtained at a wide variety of locations, so the system does not inhibit chamber design. Indeed, the input for the filter 13 could be brought from the chamber in an optical fibre.

Instead of using the spectral emission of the plasma, it is possible to use the spectral absorption by the plasma or by reaction species or product species of a defined light source, such as a frequency swept laser. This is used to produce a time-varying signal, which is analysed in the same way.

As a further example of the invention if the spectral output that is characteristic of the process development is not an atomic spectral line (Fig. 8) but rather a vibrationally broadened molecular series of lines then a particular example of the use of shape recognition techniques in the spectral domain is to search for the existence of this species by the use of an element which responds to the characteristic form. A vibrationally broadened molecular series has a spacing which is characteristic and constant in wavenumbers. Conveniently the 'Fabry-Perot' etalon has a series of passbands which are also linearly separated in wavenumbers. Therefore a specifically designed 'Fabry-Perot' etalon conveniently implements the shape recognition technique in hardware rather than software.

As a further example of the invention if the spectral output that is characteristic of the process development is as a result of chemical reaction between reactants produced as by-products of the main plasma process then such chemiluminescent spectral output is likely to form a broad continuum spectral feature. A convenient implementation of the shape recognition technique (Fig. 9) in the spectral domain is to take a rapid wide-band spectral measurement and then apply a shape recognition algorithm in the spectral domain which algorithm is derived from the specific envelope function form characteristic of the wide band chemiluminescent signal of the particular reaction that is required to be monitored. Such an approach allows strong signals derived from specific plasma processes to be eliminated prior to examination of the signal for its time behaviour.

Claims

1. A method of automatically determining the progress of a process using reactive species or generating product species, including continuously monitoring a predetermined frequency or frequency band of radiation emitted from or absorbed by the species, developing a graphical or numerical output corresponding to the level of emittance or absorption, and electronically comparing the shape of that output with a predicted output or trend to provide an indication of the progress of the process.

2. A method as claimed in Claim 1, further comprising generating a control signal for controlling the process when a predetermined stage in the process progress is attained.

3 A method as claimed in any one of Claims 1 or 2, wherein the process is plasma based.

4. A method of processing a semiconductor workpiece including determining the process progress as claimed in any one of claims 1 to 3 and controlling the process in response to the indication provided.

5. A process control system for controlling a process using reactive species or generating product species, including means for continuously capturing an optical frequency differentiated sample of radiation from the process, a detector for producing an output indicative of the time varying intensity of the radiation, and shape recognition means in the temporal domain for comparing the output against a predicted output or

trend to provide an indication of progress of the process.

6. A system as claimed in claim 5, wherein the optical frequency differentiated sample of radiation is processed by a shape recognition means operating in the optical frequency domain prior to its processing in the time domain.

7. A system as claimed in claim 6, wherein the shape recognition means operating in the optical frequency domain is a specifically designed 'Fabry-Perot' etalon having a series of passbands which are linearly separated in wavenumbers which correspond to the vibrationally broadened molecular series of the chemical constituent which is characteristic of the process being monitored.

8. A system as claimed in claim 7, wherein the 'Fabry-Perot' etalon is scanned in centre frequency by continuously tilting it about a rest position.

9. A system as claimed in claim 6, wherein the frequency differentiated sample of radiation is derived from a monochromator means and the shape recognition means operating in the optical frequency domain is implemented in software following the detection of the signal and its conversion to an electrical signal.

10. A system as claimed in Claim 5, wherein the radiation capturing means includes an optical output, a thin film filter and an interference device.

11. A system as claimed in Claim 10, wherein the interference device is a 'Fabry-Perot' etalon.

12. A process control system wherein a time evolving spectral output from a reaction is detected by a spectral detection means and then used in combination with the application of shape recognition techniques to provide a continuous measure of process progress against a predicted trend.

13. A process control system as claimed in Claim 12, wherein the spectral detection means includes the combination of a thin film filter with an interference means.

14. A process control system as claimed in Claim 13, wherein the interference means is a 'Fabry-Perot' etalon.

15. A process control system as claimed in Claim 13, wherein the interference means is a scanned 'Fabry-Perot'.

16. A process control system as claimed in any one of claims 12 to 15, including a digital filter for determining the shape of the time evolving spectral output.

17. A process control system as claimed in any one of Claim 12 to 15, wherein the shape recognition is achieved by a series of masks derived from different time epochs using a Gradiometer transform.

18. A process control system as claimed in any one of Claims 12 to 15, wherein the shape recognition is achieved by a series of masks derived from different time epochs using a Fourier Transform.

19. A process control system as claimed in any one of claims 12 to 15, wherein the shape recognition is achieved by a series of masks derived from different time epochs using a Laplace Transform.

20. A process control system as claimed in any one of claims 12 to 15, wherein the shape recognition is achieved by a series of masks derived from different time epochs using the Kohonen self organising map.

21. A process control system as claimed in any one of claims 12 to 15, wherein the shape recognition is achieved by a series of masks derived from different time epochs using the cellular neural network paradigm.

22. A process control system as claimed in any one of claims 12 to 15, wherein the shape recognition is achieved by a series of masks derived from different time epochs using Polynomial Interpolated Measures.

23. A process control system as claimed in any one of claims 12 to 15, wherein the shape recognition is achieved by a series of masks derived from different time epochs using the method of Fractals.

24. A process control system as claimed in any one of Claim 12 to 23, wherein the spectral detection means includes a dispersive grating monochromator.

25. A process control system as claimed in any one of claims 12 to 23, wherein the spectral detection means includes a scanned 'Fabry-Perot' interferometer.

26. A process control system as claimed in any one of Claims 12 to 23, wherein the spectral detection means includes a Fourier Transform Spectrometer.

27. A process control system as claimed in any one of claims 12 to 26, wherein a multiplicity of spectrum parts are examined simultaneously.

28. A process control system as claimed in any one of claims 12 to 26, wherein the spectral detection means detects the absorption spectrum of light of a particular characteristic wavelength.

29. A process control system as claimed in any of claim 28, including a laser as a light source for providing the light of the particular wavelength.

30. A process control system as claimed in any of claims 29, including a frequency swept laser as the light source.

31. A process control system as claimed in any one of Claims 12 to 26, wherein the process is plasma based.

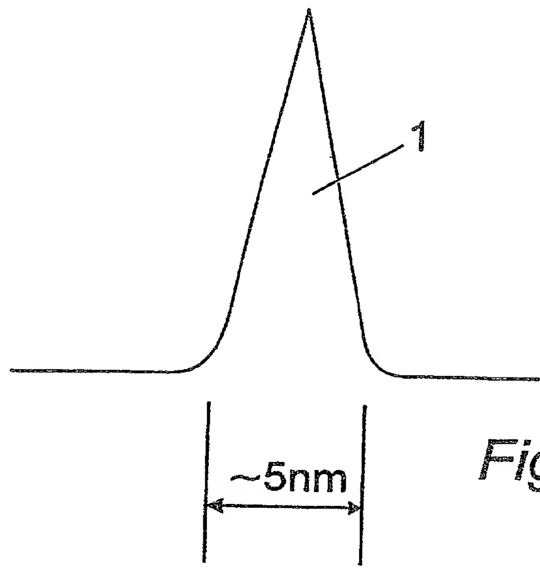

Fig. 1

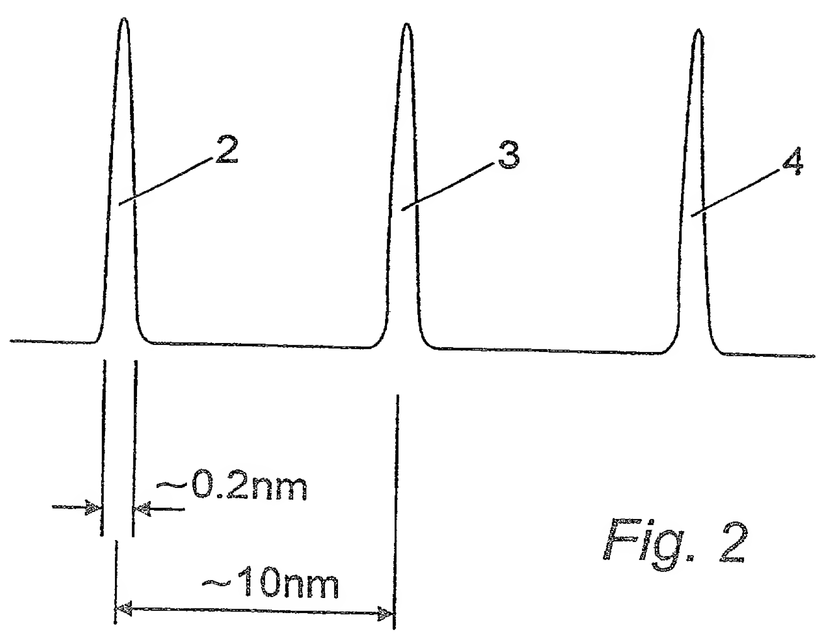

Fig. 2

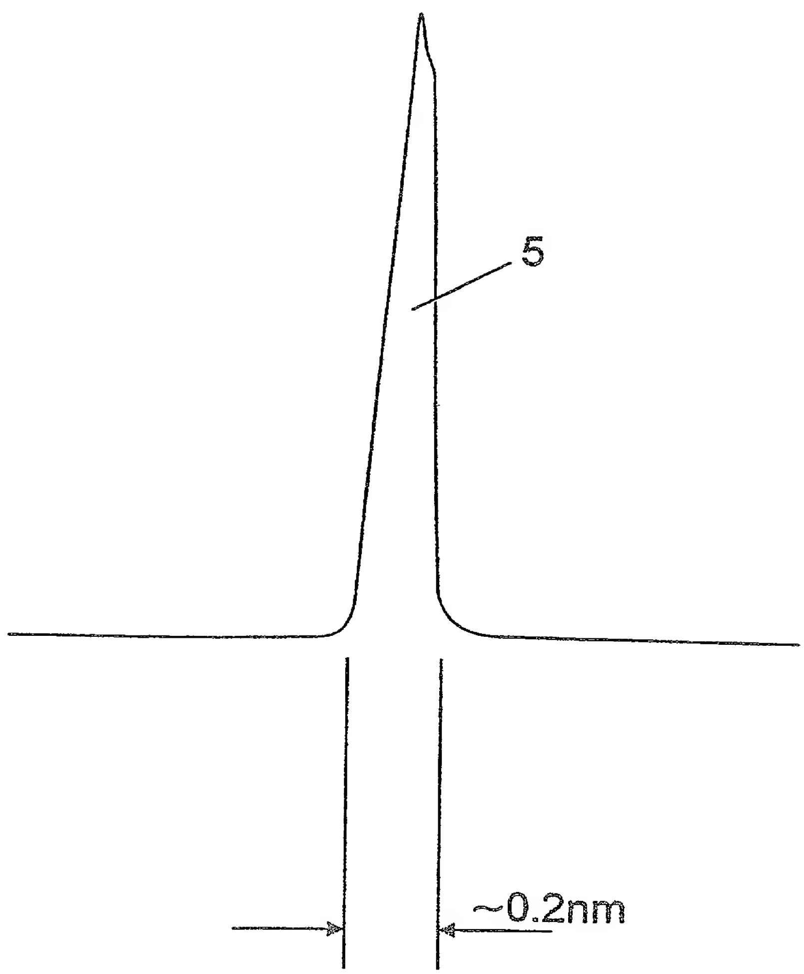

Fig. 3

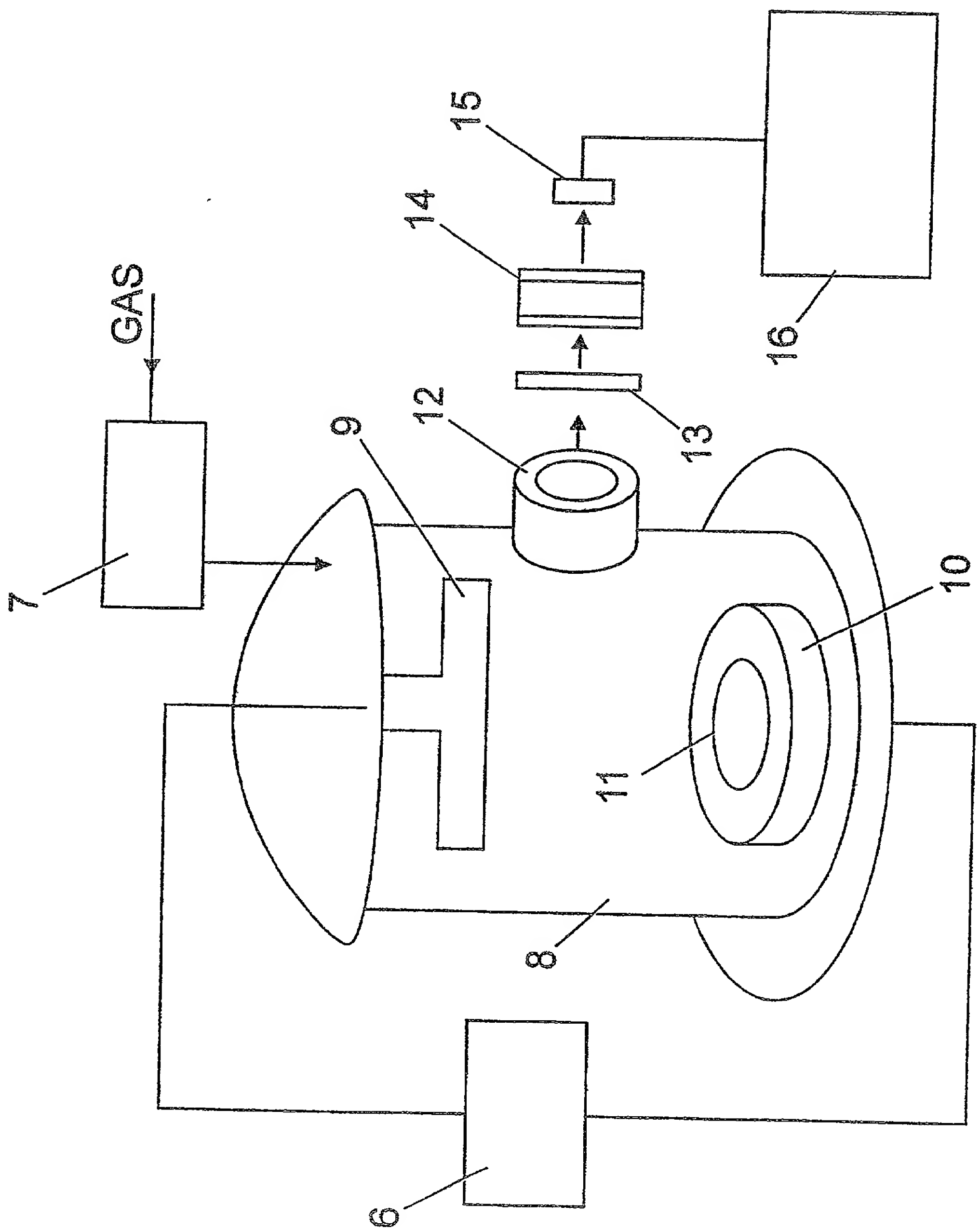

Fig. 4

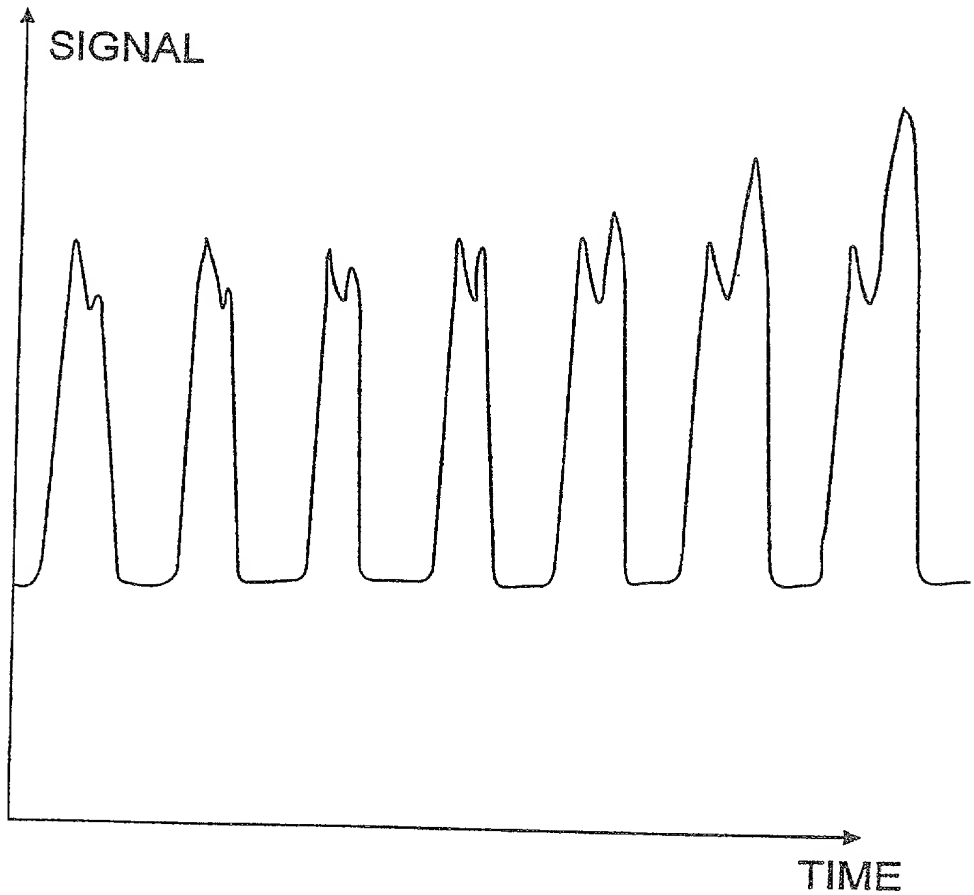

Fig. 5

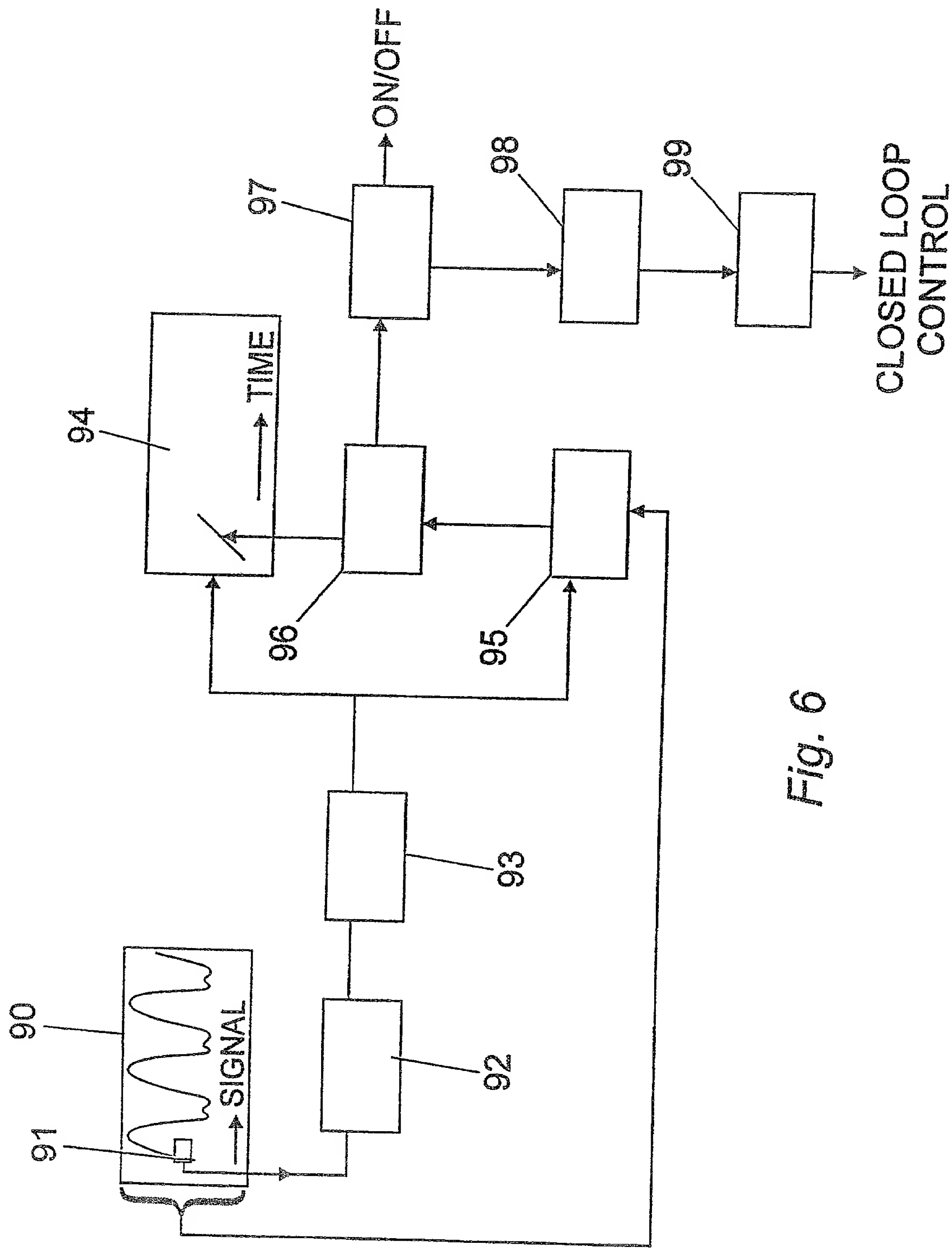
ON/OFF
97
98
99
CLOSED LOOP CONTROL
94
TIME
96
95
90
91
SIGNAL
92
93

Fig. 6

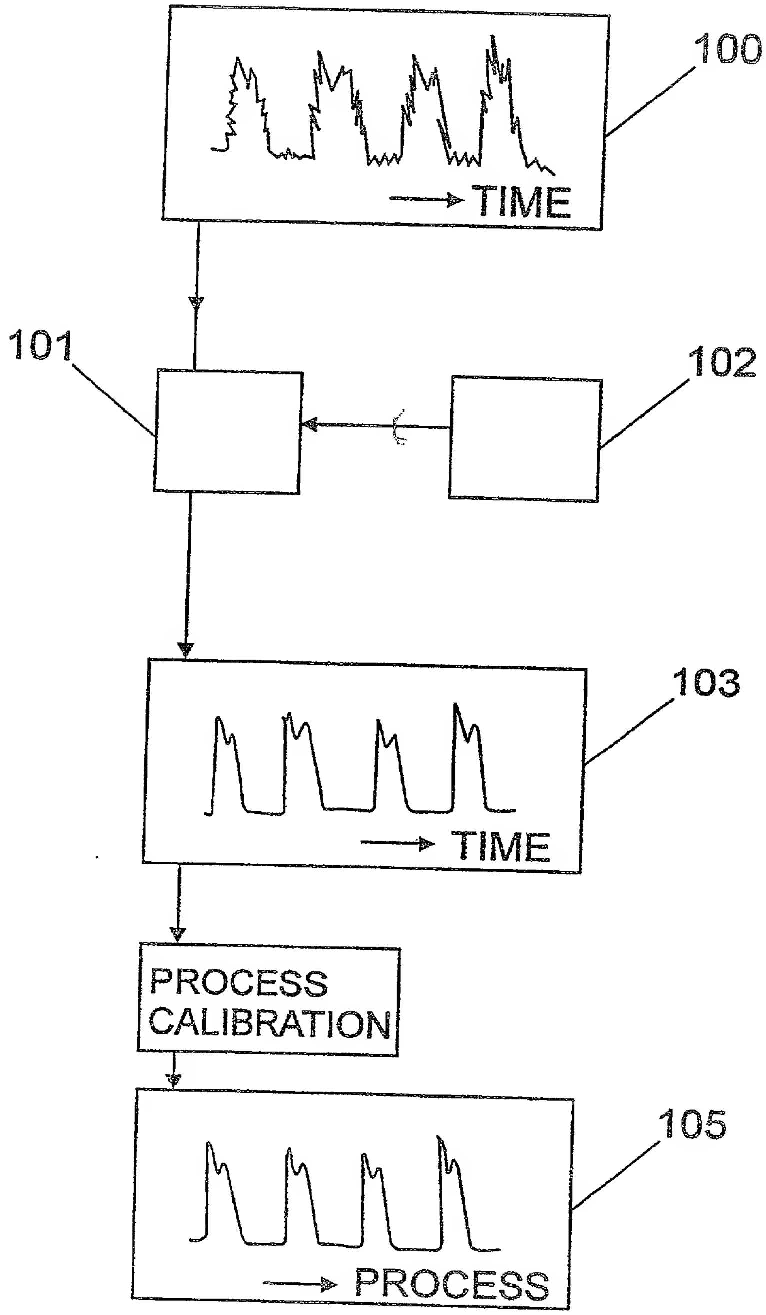

Fig. 7

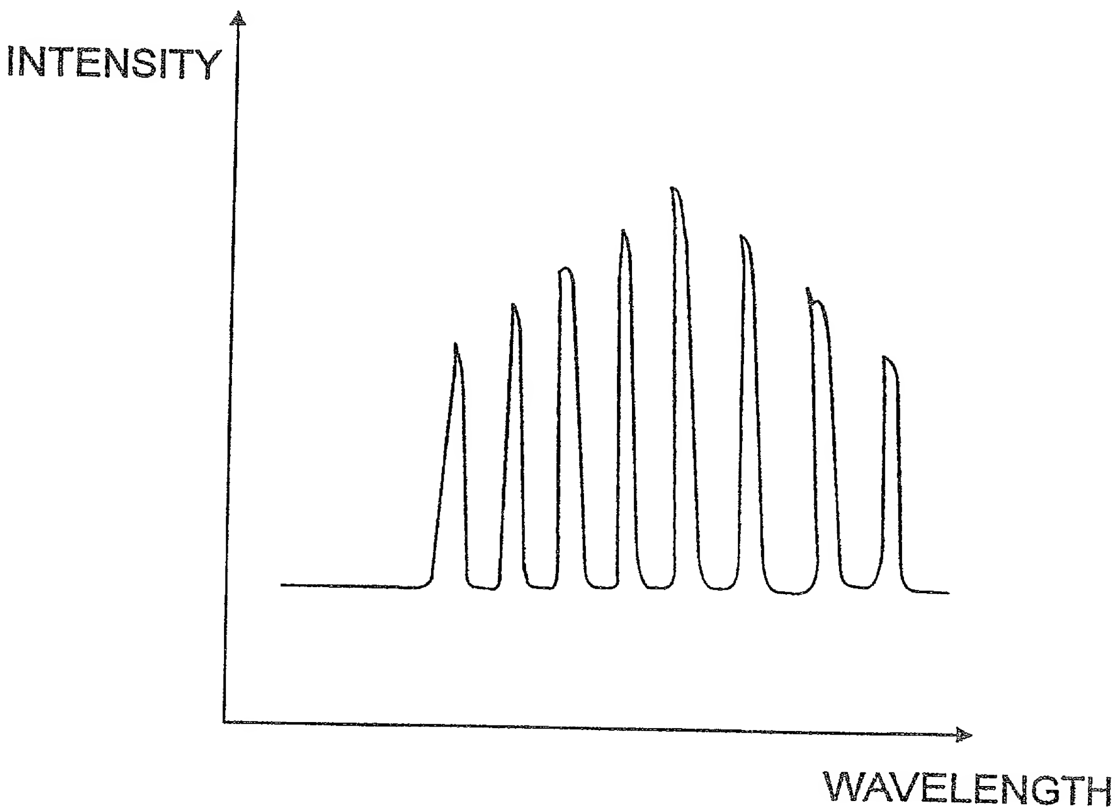

Fig. 8

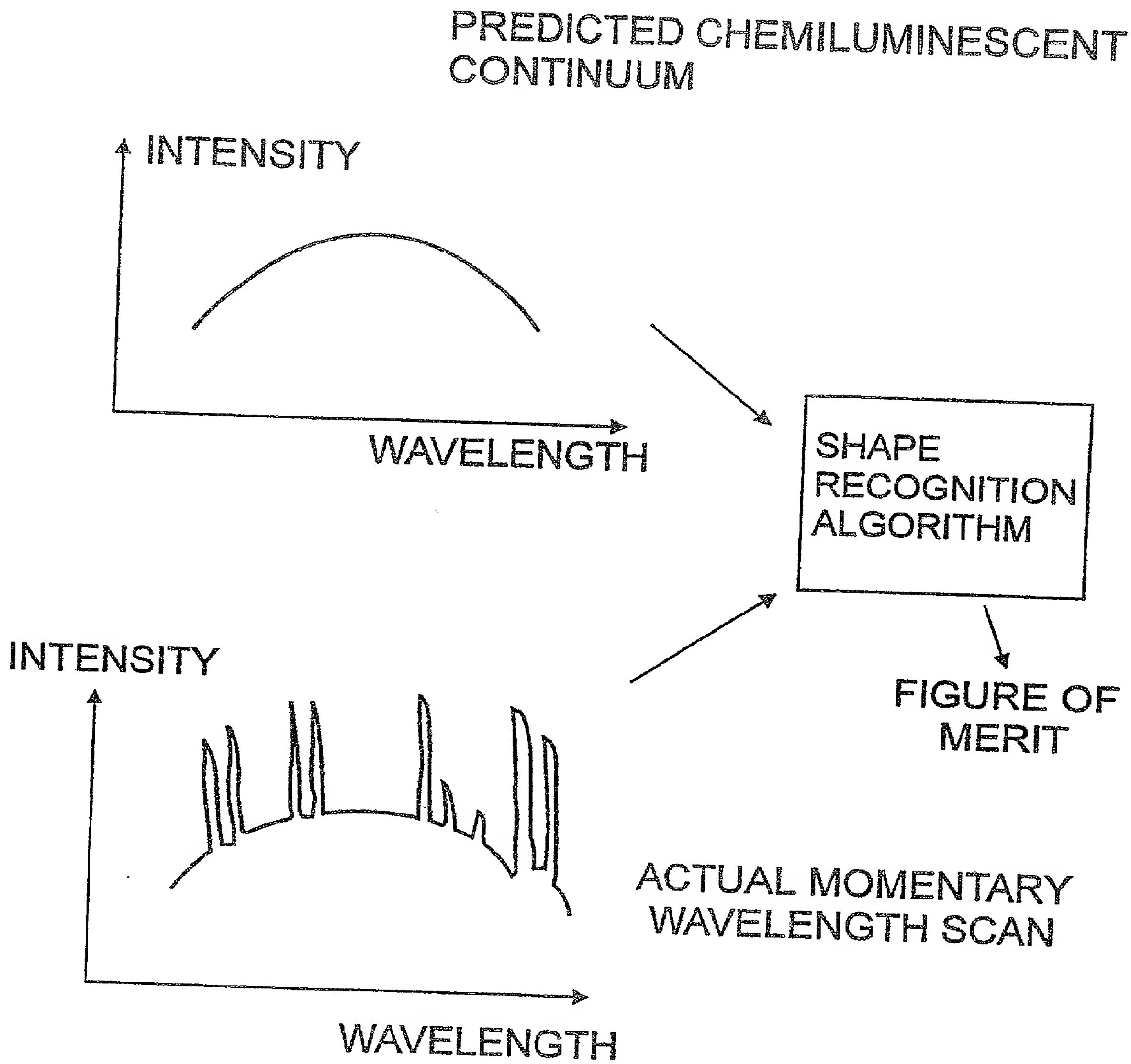
PREDICTED CHEMILUMINESCENT CONTINUUM
INTENSITY
WAVELENGTH
SHAPE RECOGNITION ALGORITHM
FIGURE OF MERIT
INTENSITY
ACTUAL MOMENTARY WAVELENGTH SCAN
WAVELENGTH

Fig. 9

(Application Number) (Filing Date) (Status - patented, pending, abandoned)

(Application Number) (Filing Date) (Status - patented, pending, abandoned)

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith:

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

1-00

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Fourth inventor's signature ______ Date ______

Residence ______

Citizenship ______

Post Office Address ______

Full name of fifth joint inventor, if any (given name, family name) ______

Fifth inventor's signature ______ Date ______

Residence ______

Citizenship ______

Post Office Address ______

Full name of sixth joint inventor, if any (given name, family name) ______

Sixth inventor's signature ______ Date ______

Residence ______

Citizenship ______

Post Office Address ______

Full name of seventh joint inventor, if any (given name, family name) ______

Seventh inventor's signature ______ Date ______

Residence ______

Citizenship ______

Post Office Address ______

Declaration and Power of Attorney For Patent Application
English Language Declaration

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled IMPROVED PROCESS MONITOR, the specification of which is attached hereto unless the following box is checked:

☒ was filed on 12 July 1999 as International Application Number PCT/GB99/02082 and was amended on 31 July 2000 (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR § 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. §119(a)-(d) or § 365(b) of any foreign application(s) for patent or inventor's certificate, or § 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)			Priority Not Claimed
GB	9815005.5	11 July 1998	☐
(Number)	(Country)	(Day/Month/Year Filed)	
GB	9824676.2	11 November 1998	☐
(Number)	(Country)	(Day/Month/Year Filed)	

I hereby claim the benefit under 35 U.S.C. § 119(e) of any United States provisional application(s) listed below.

(Application Number)	(Filing Date)
(Application Number)	(Filing Date)

I hereby claim the benefit under 35 U.S.C. § 120 of any United States application(s), or 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. § 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR § 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application: